

THE
NAVIGATOR'S GUIDE,

TO

533.e.8.

The Oriental or Indian Seas²:

OR,

THE DESCRIPTION AND USE OF
A VARIATION CHART of the Magnetic Needle,
Designed for shewing the LONGITUDE,
Throughout the principal Parts of
THE ATLANTIC, ETHIOPIA, and SOUTHERN OCEANS;
Within a Degree, or Sixty Miles.

With an Introductory Discourse, concerning the Discovery
of the Magnetic Variation, the finding of the Longitude
thereby, and several useful Tables.

By S. DUNN, Teacher of Mathematics, LONDON,

L O N D O N,

Printed for the Author; and Sold by him. Likewise Sold by H. Gregory,
Leadenhall-Street; T. Newman, in Exeter 'Change; A. Smith,
near Charing Cross; Mathematical Instrument-Makers.

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bound, 12 s. by the same Author, may be had.

The Variation Chart, and Mercator's Chart, on three Sheets of Imperial
Paper, with the Description and Use of them, 1 s.

THE

NAVIGATOR'S GUIDE

THE OCEAN OF INDIAN SEAS
BY THE LIEUTENANT-GOVERNOR OF THE BENGAL PRESIDENCY

THE DECEASED OF THE INDIAN SEAS
A VARIATION CHART OF THE INDIAN SEAS
BY THE LIEUTENANT-GOVERNOR OF THE BENGAL PRESIDENCY

THE ATLANTIC OCEAN
A VARIATION CHART OF THE ATLANTIC OCEAN
BY THE LIEUTENANT-GOVERNOR OF THE BENGAL PRESIDENCY

THE PACIFIC OCEAN
A VARIATION CHART OF THE PACIFIC OCEAN
BY THE LIEUTENANT-GOVERNOR OF THE BENGAL PRESIDENCY

THE INDIAN OCEAN
A VARIATION CHART OF THE INDIAN OCEAN
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THE ARABIAN SEA
A VARIATION CHART OF THE ARABIAN SEA
BY THE LIEUTENANT-GOVERNOR OF THE BENGAL PRESIDENCY

THE BAY OF BENGAL
A VARIATION CHART OF THE BAY OF BENGAL
BY THE LIEUTENANT-GOVERNOR OF THE BENGAL PRESIDENCY

TO

THE 'HONOURABLE THE COURT OF DIRECTORS
OF THE UNITED COMPANY OF MERCHANTS OF ENGLAND
NAVIGATOR'S GUIDE
TRADING TO THE EAST INDIES:

UNDER WHOSE PREDECESSORS FAVOUR AND PROTECTION,
THE BRITISH MATHEMATICIAN, EDWARD WRIGHT,
OF LONDON, PUBLISHED HIS INVENTION OF THE
TRUE SEA CHART, COMMONLY CALLED MERCATOR'S;

AND BY WHOSE ENCOURAGEMENT,
THE INTRODUCTORY PLAN OF THIS WORK WAS LAID,
IN A TREATISE OF PRACTICAL ASTRONOMY,
LATELY PUBLISHED:

THIS FIRST VARIATION CHART OF THE MAGNETIC
NEEDLE, THAT HAS EVER BEEN DRAWN FROM ORIGINAL
PRINCIPLES, CONFIRMED BY THE ASTRONOMICAL
OBSERVATIONS OF THE COMMANDERS AND
OFFICERS OF SHIPS IN THE COMPANY'S
SERVICE,

IS,

WITH THE GREATEST DEFERENCE AND RESPECT,
MOST HUMBLY INSCRIBED,
BY THE AUTHOR,

London,
10 Nov. 1775.

S. DUNN,

THE HONOURABLE THE COURT OF DIRECTORS
OF THE UNITED COMPANY OF MERCHANTS OF ENGLAND
NAVIGATOR'S GUIDE
TRADING TO THE EAST INDIES:

TO
ORDER WHOSE FAVORABLE FAVOUR AND PROTECTION
THE COURT OF DIRECTORS OF THE UNITED COMPANY OF MERCHANTS OF ENGLAND

OF LONDON, TRADING TO THE EAST INDIES, OF THE
THE EAST INDIA COMPANY, COMMONLY CALLED MERCHANTS;

AND BY WHOM THE COURT OF DIRECTORS OF THE UNITED COMPANY OF MERCHANTS OF ENGLAND, TRADING TO THE EAST INDIES, OF LONDON, TRADING TO THE EAST INDIES, OF THE EAST INDIA COMPANY, COMMONLY CALLED MERCHANTS;

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THE
NAVIGATOR'S GUIDE

TO

THE ORIENTAL OR INDIAN SEAS, &c.

Of the Utility of Navigation.

1. **N**AVIGATION, Commerce, and an Intercourse with distant Countries which are widely separated by the oceans, are found so beneficial to nations in general, and to the individuals of them in particular, that a denial of those advantages would be a dissent from the general opinion of the most rational part of mankind, and an argument for re-establishing men in that wild and uncultivated state in which it may be supposed many of the more ancient inhabitants of the world subsisted, if not that savage and barbarous situation in which many of the human race now are, according to the testimony of voyagers and travellers.

2. The instruments whereby navigation is performed, are ships, the noblest machines that have been invented; these are guided according to art, and somewhat in the direction of the winds, over the deep waters of the oceans and seas, by a most ingenious and enterprising part of the community, Navigators and Mariners, to whose industry and resolutions persons on land owe for all the benefits and advantages derived from this art; and therefore these men may be justly styled, a most useful and valuable part of mankind.

3. The whole art of navigation, taken in its greatest extent, may be considered as consisting of a variety of parts. First, the construction and building of ships, so that they may be able to bear the force of the winds, and the violent agitations of the waters of the ocean; this properly constitutes

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tutes the art of ship-building. Secondly, the managing of their rigging and tackle, both in and out of port, so that they may be in a proper state for sailing, or otherwise, as occasion requires, which business falls to the mariner or working seaman. Thirdly, the guiding of ships from one place to another near the sea coasts, commonly called coasting, sometimes in sight of land, at other times more remote. This is performed by the log line and sea compass; the former measuring the distance sailed; the latter the course, whereby are known the distance and position of the place sailed from, or other places after the ship has been any determinate time in motion. But, fourthly, when a voyage is by this method made, upon the vast and extended oceans and seas of great extent, such are the errors arising from an inability to steer the ship under any course that is desirable, and an inability to measure her distance sailed correctly, that frequently after she has been off from the land for a considerable time, her navigators and mariners are deceived by this method of sailing, from one to two or three hundred miles or more, and therefore have need of some farther and better help; and in such case but little can be done without the practice of Astronomy.

4. But, however useful Astronomy may be in the art of Navigation, it cannot be applied but at particular times, when the Celestial bodies are visible, and at proper places in the Heavens; whereas the old method of sailing by log line and compass is universal, and applicable at all times and places; it may be farther noted, that almost half the time a ship is on her voyage, namely, the night-time, without mentioning the interruptions by foggy weather, the horizon of the sea is so imperfectly defined, that but little use can be made of it in correcting the latitude by an observation; and observations for the longitude in the night-time are attended with much more uncertainty: and therefore all improvements on the old method of sailing are of the utmost consequence, and ought to be admitted whenever they can be made.

5. The mathematical proportions which hold good in the method of sailing, are as follows: the radius or sine of 90 degrees, and the distance sailed; the cosine of the course, and

and the true difference of latitude, the sine of the course, and the departure, these are in the same direct proportion to each other. And farther, the radius, and the meridional difference of latitude, the tangent of the course, and the true difference of longitude, these are in the same direct proportion to each other, according to Edward Wright's, commonly called Mercator's Sailing. Many other proportions arise from the same principles. There is another method practised by navigators, called Middle Latitude Sailing, the invention of some ingenious persons of later times, which, although it be not correctly true in theory, may be applied on many occasions without much error; and as the method of calculation by this method is somewhat less dependant on tables, the more ingenious mariners do frequently apply it with success.

6. But, before the course of a ship can be duly ascertained, her leeway should be determined, and this cannot be so accurately found as is requisite; the variation of the Magnetic Needle, or its deflection from the true meridian of the place where the ship is, should also be known, this is usually found by the azimuth compass from one day to another, and the course thereby corrected, which sometimes, without such allowance, might be uncertain to one, two, or more points of the compass. But, when all possible care has been taken in correcting the lee-way and variation, an error will remain in the distance measured; and although an observation may correct the latitude supposedly arrived in by the ship's reckoning, to one or two minutes of a degree, the apparent revolution of the heavens hath denied a foundation for observing the longitude to that accuracy; and as this part of navigation is imperfect, and otherwise the security of ships at sea would be more certain, different nations have long since offered rewards for a method of determining the longitude at sea within 30, 40, or even 60 geographical miles, and such a one as may be brought into general practice.

7. To these more public overtures, have been added, the munificence of Princes, Philosophers, Mathematicians, and Mechanics have exerted themselves and given methods, but the skilful Navigator knows best to what degree of accuracy these methods may be depended on, and the difficulties he meets

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meets with in practising them. It is surprizing that much greater errors do not happen in the practice than are found by experience, because in one of these methods, by a watch, if it err from its rate of going, and thereby deceive the Navigator but 4 seconds of time *per* day for a month, it will cause an error of 30 miles at the Equinoctial, supposing no error to happen either in the calculation or observation. And in the observations by the Sun and Moon's angular distances, or angular distances of the Moon and Stars, the Moon's apparent recession from West towards the East amongst the Stars, being, at the most, but a little more than 14 degrees *per* day, and less for the Sun, it follows, that if the observer for the longitude, by this method, errs in taking the Moon's angular distance from the Sun or fixed Stars, but a little more than a minute of a degree, it may produce an error of 30 miles in longitude at the Equinoctial; without mentioning the difficulties there may be in predicting the Moon's place absolutely correct, the making of proper allowances for refraction, and other things belonging to the observation and calculation.

8. There is a third method whereby the longitude at sea hath been formerly sought; namely, by the variation of the Magnetic Needle, or its horizontal deflection from the meridian of the place of observation; which variation having been found different at different places in longitude as well as latitude, it has been attempted to find the degrees of variation, not only near the lands, but in the open seas, and the longitudes of the same places, thereby to find the place of the ship.

9. When, or by whom, the variation of the Magnetic Needle was first discovered, is not certainly known. Historians will have it that the attractive power of the loadstone was known to the ancient Philosophers so early as the days of Thales the Milesian; but that the power it had of disposing slender pieces of iron touched by it, to put themselves in a Northwardly and Southwardly direction, was not known in the European parts till the year 1260, when the mariner's compass complicated thereby was introduced; and that about the year 1500, Sebastian Cabor, a Venetian, discovered the variation to be a real property of the needle,

which before had been taken to be an erroneous position arising from a defect in the wires of the compass.

10. The principal discoveries which were afterward made, seem to have been near London; for in 1576, Robert Norman, at Wapping, discovered the dip of the needle to be a real property; in 1580, he observed the variation there, with his friend Mr. Burrows, $11^{\circ} 15'$ East; but the change of the variation is said to have been the discovery of Mr. Henry Gellibrand about the year 1625, by the needle of a large dial, which had been set up in Privy Garden, Whitehall.

11. For the year 1589, Mr. Edward Wright, in his Treatise of Navigation, gave a table of variations which he had observed that year by sea and land, and in opposition to the opinion of M. Peter, of Medina, who had denied the variation, proved that the quantity of it was then different at different places, and that allowances should be made for it in the course of a ship. He also considered particularly the inclinatory property, and gave the measure of the Earth's semi-diameter taken by himself, with an instrument of his own constructing, on Mount Edgcomb near Plymouth; an observation applicable for regulating the length between knot and knot, in the log line used in sailing by the compass.

12. About those times the hypothesis of magnetic poles, meridians, and an axis, was started, by Gulielmus Nautonerius a Frenchman, and Anthony Linton an Englishman; and it was conceived that, by such an hypothesis, the latitude and variation being given, the longitude of a place might be found by the calculation of spherical triangles. But it was soon discovered, that this method was imperfect, and that no such poles existed in the surface of the sphere. Nevertheless, the navigators of those times thought the variation of the compass the best guide for finding out an haven or port, when they had lost their longitude at sea by reckoning, and therefore called it the haven-finding art, and despised those who would not use so ready an help in time of distress; and this was the opinion of Wright himself, as appears by his own words. In those times we do not find they attempted to draw any lines of equal variation on their charts, but set them down in numbers.

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13. From

13. From the time of Edward Wright, 1589, Astronomers began to entertain better hopes of finding the longitude at sea, by the Moon's receding from the Sun and fixed Stars; the accurate observations of the noble Tycho Brahe having fixed the places of the principal Stars, and raised an expectancy that the like might be done for the Moon. This gave rise to several observatories throughout Europe, where the observations have been continued to be made to the present time by the most exquisite astronomical instruments.

14. But the great reviver of the magnetic variation seems to have been Dr. Edmund Halley, by a chart of those variations which he drew for the year 1700, continuing the lines of equal variation over the seas, from the Northern part of the Western Ocean to the Southern part of the Southern Ocean, and likewise over the Indian Seas. As the Doctor was in the Island St. Helena in the year 1677, and some voyages used in that work were made not long before its publication, it may be supposed, that the whole could not have been less than the result of 20 years study and experience. The Doctor's Chart of Variations is frequently to be met with, drawn to a scale of a little more than half an inch to ten degrees of longitude, and according to Wright's Projection, for the year 1700; but I have seen a Delineation, after the same manner, of a little more than an inch and a quarter to ten degrees of longitude, printed at Amsterdam for the year 1700, under the Doctor's name.

15. In 1744 Messrs. Mountain and Dodson drew the variation lines to a chart of Wright's projection, agreeing very nearly in the scale and coasts with the last-mentioned by Dr. Halley; and in 1756, they drew another to the like scale and coasts, with the variation lines for that year; which M. Bellin at Paris has imitated, by first drawing the coasts to a scale a little less, and then by an allowance for the increase of variation, carrying the variation lines forward to the year 1765.

16. The smallness of the scale to which all those former charts have been drawn, could not but render them very unfit for any attempt of the longitude at sea by them, however correctly they may be supposed to have been drawn; and

and as the variation at sea was then chiefly settled by the ship's reckonings, and such reckonings are liable to err much in the longitude, it is surprizing to find them no less perfect; for in this subject, neither Mathematicians nor Philosophers have had any theory to help out either delineations or tables; every point found on the chart must have been the work of real experience and observation, and these points being connected, gave the lines of equal variation.

17. Towards the end of the year 1773, being desired by several respectable persons to draw up and publish a Treatise on *Practical Astronomy*, I finished that work the end of October 1774; and it may now be had either of me, or the persons named for selling this work. In that Treatise, I have delivered the most essential principles and methods for making such astronomical observations as are requisite for settling the latitudes and longitudes of places by sea and land, and for applying them to Geography and Navigation. In the treatise is a catalogue of 300 Fixed Stars, settled in right ascension and declination to the beginning of the year 1780, calculated by me, which is here mentioned; because M. de la Lande's Catalogue in M. de la Caille's Ephemeris, is carried forward to the same year, and it cannot be supposed that I borrowed his numbers, as I have my calculations by me made years since, and my book was published a considerable time before his.

18. Having given in my fore-mentioned treatise, the most effectual methods for settling the latitudes and longitudes of places, and to obtain exact and accurate variation charts, I have now, from a few observations, drawn a VARIATION CHART of the *Atlantic, Ethiopic, and Southern Oceans*, for the year 1776, designed for determining the Longitude in those Seas, within a Degree, or sixty Miles. The manner in which I have proceeded to supply the use of a theory in the drawing of this chart, has been explained before the Honourable Gentlemen to whom the work is inscribed; but the theory itself, which the proceedings were formed by, hath not been yet delivered. It may seem surprizing, but it is true, in going through the principal parts, and almost all this vast ocean, I wanted no more to begin and finish the work by, than observations made of the variation at three

or four places, near the lands and the other places on the oceans, became regulated by the theory which I have just mentioned.

19. By this method the Islands St. Helena, Ascension, Trinidada, &c. being laid down by their latitudes and observed variations, their longitudes agreed very nearly with astronomical observations made at those places. By the same method, the longitude of Cape Negro, on the West Coast of Africa, which had been variously laid down by Geographers, and which no astronomical observations could be found for, became considerably corrected. But although these circumstances afforded no slight grounds to suppose that the lines might be depended on for all parts of the intermediate oceans, it would have been with the greatest diffidence I could have proposed this work for public use, without such farther proofs as were to be had; and therefore I solicited the Court of Directors, for such observations as were proper for the purpose; and they were pleased to grant me access to the Journals of the commanders and officers of ships in their service.

20. With the greatest readiness and pleasure, I would here give the names of those gentlemen, many as they are, and the observations which they made: but there appear to me two objections against it; one is, that I do not know they would approve of my publishing their names in this manner; another is, that if, on a comparison of their observations, any different conclusions should appear to arise, it might cause reflections, whilst there is no real foundation for any such. I think it rather most proper, at present, only to mention that it hath surprized me, in looking over their Journals, to find with what care, diligence, and ingenuity, those Gentlemen have applied the lunar observations, in correcting the reckonings of their ships; and should it be thought proper to mention their names, they may be inserted in the farther proceedings of this work.

21. I shall beg leave to mention one particular circumstance; Mr. Kidd, after having favoured me with many observations of his own, introduced me to Mr. Maw, both of these in the India service, some months after the Chart was drawn and settled as it now appears: I had not been
able

able to find any late observation of the variation at Tristan de Cunha, in the Southern Ethiopic Ocean. Mr. Kidd gave me the latitude $36^{\circ} 55'$ S. longitude $10^{\circ} 34'$ W. without the variation at Tristan de Cunha, but the variation taken East of it. Mr. Maw gave the latitude $37^{\circ} 0'$ S. and when the bearing was S. W. by W. $\frac{1}{2}$ W. 17 or 18 leagues, by the mean of 3 distances of Sun and Moon longitude $10^{\circ} 28'$; by the mean of 3 others $10^{\circ} 7'$; of 3 others $10^{\circ} 10'$; of three others $10^{\circ} 11'$; from which observations by the Moon, the longitude of that place on the sea could not much exceed 10 degrees; the variation observed at the same place was a little more than 5 degrees. If an allowance be made for the change of variation, and the longitude of this Island inferred from it, there will be less than half a degree of difference between the determination by the Moon and the Chart. Had I laid down these Islands by some reputable authorities, the longitudes thereby would have differed eight degrees from one another.

22. I have been the more particular in this case, to shew what errors might have happened by the introduction of more sea coasts, where the longitudes have not been well ascertained. It was with difficulty the longitudes of the Cape de Verde Islands were determined, as the best that I could consult differed a degree and half in the longitude of St. Jago, the principal of them; had they been placed more East, it would have been more agreeable with my theory, although the variation lines would have gone with the Islands; and I am inclined to think, they may need some small correction that way, but have taken what passed for the best authorities.

23. As the manner in which this Chart is drawn differs from all others that have appeared, and some persons may fancy it to be a plain Chart, whilst it is not; it may therefore be proper to explain its construction. The description at the bottom of the Chart may be sufficient for more intelligent persons, but a farther description is as follows: The degrees of latitude are every where equal, and they are shewn by straight lines parallel to each other; as these are so far distant from each other, it is easy to assign a place on the Chart, without erring a quarter, or even a sixth, part of a degree

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degree in latitude. The degrees of longitude are shewn by straight lines, equidistant from each other at the equinoctial, as the degrees of latitude; but these are so contrived, that they approach toward each other toward the North and South, under the parallelism of the degrees of latitude, nearly as the meridians on the globe; this construction ariseth from mathematical principles, and not only takes off that enlarging of the degrees toward the poles, which would be introduced by Wright's construction, but at the same time causeth the variation lines to fall in a more elegant order on the Chart.

24. The most natural order which the meridians and parallels could have had, would have been their standing almost at right angles to each other; but when it is considered, that the Chart is not only contained in a much less space otherwise, but shews the path of the ship in a better manner, without any diminution of the scale, and that a Mercator's delineation is added, for finding the course to be steered, from the latitude and longitude arrived in, to the latitude and longitude of any other place; any objection to this new mode of delineation must have but little weight with reasonable persons, since it is a property which belongs to many good maps, and so many advantages are here derived from it.

25. Having given an account of the rise and progress of the variation of the compass, and shewn the various steps by which improvements have been made therein from time to time; I proceed to shew, what are the proper instruments to be used in discovering the longitude at sea by this method, and what are the calculations to be made, before the Variation Chart is applied.

26. The instruments to be used are, either an Hadley's Quadrant or Sextant. The manner of adjusting and using this instrument is so well known to Navigators, that it seems almost unnecessary to mention them; but, if the Reader is desirous, he may find these things, with the application of this instrument, largely explained in my Treatise of Practical Astronomy.

27. The Navigator should likewise have the use of an azimuth compass. The manner of using this instrument is delivered

delivered in a Pamphlet by the Maker, and it is to be applied for determining on what point of the compass, in degrees and minutes, the Sun bears at the making of an observation. The quadrant is for taking the latitude of the place, and also the altitude of the Sun when the longitude is observed for; no great nicety is required in either of these, nor that the azimuth compass should determine the magnetic bearing of the Sun nearer than to a quarter of a degree. A much less accuracy may be dispensed with, if several observations be taken nearly at equal intervals of time, and the medium of them set down for the observation.

28. He should likewise have a table of logarithmic lines, tangents, and secants, such are in the common books of navigation; the variation chart here described; a table of the Sun's declination; and, if he chooses to observe for the longitude by this method in the night-time, he should have a table of the declinations of the principal fixed Stars. Both these latter tables are contained in this Tract, which, if he hath no other books, there will be wanted only the logarithms before-mentioned.

29. The observations and calculations that are to be made, in order to find the variation of the compass, are so well known to Navigators, as being practised almost every day by them, that it seems almost unnecessary to exemplify them here; the calculations at large, with remarks on them, are in my *Practical Astronomy*. The proportion for the amplitude is thus: As the cosine of the latitude is to the sine of the declination, so is radius to the sine of the amplitude. But when the azimuth of the Sun is required, a larger process is used as follows: The co-latitude, the co-altitude, and the polar distance, are written under each other, and the half sum of them taken, from which the polar distance being subtracted, leaves a remainder; then the log-cosecant of the co-latitude, taking ten from the index; the log-cosecant of the co-altitude taking ten from the index; the sine of the half sum, and the sine of the remainder, being added together, and their half sum found in log-sines, double the arch to which that is a co-sine, is the azimuth or true bearing of the Sun from the point of the Horizon under the elevated pole, whether it be North or South latitude.

30. Having

30. Having found either the true amplitude or the true azimuth, the difference between it and the magnetic amplitude or azimuth respectively is the variation of the compass. There are several cases concerning the variation, whether it be Easting or Westing, which are so well known to Navigators, as being a part of that art with which they are daily conversant; that it seems needless to particularize them here. The like may be said concerning observations for the latitude.

31. Having found the quantity of the variation, whether it be Easting or Westing; and having the latitude of the place somewhat near the truth, either by the ship's reckoning or an observation, guide your eye along that latitude, on the Variation Chart, between the parallels, until you come to such a curve line of the variation as you have observed, and from that place of intersection or meeting, guide your eye Northwardly or Southwardly, under the direction of the inclined meridians; and the figures in the margin at top or bottom will shew the degrees and parts of a degree of longitude from London, either Easting or Westing.

32. It is presumed that, by this method, the longitude may be taken within the seas for which the Chart is drawn for some years to come, without much need of correction; but as the magnetic system may not be supposed to be often at a stand or stationary, at the end of many years, the lines of equal variation may acquire a different situation amongst the meridians and parallels of latitude, in which case it will be very easy, by the help of a few observations, to introduce such corrections, either additive or subductive, as may make it fit to be depended on with certainty.

33. The latitude and longitude of the ship being thus determined, it becomes a question in Mercator's, or rather Wright's Sailing, to determine what course the ship shall steer, to arrive at any other place whose latitude and longitude are given; but as this may be thought a little tedious, I have drawn a delineation of this kind, which, being applied, will solve this useful additional problem by inspection. In this delineation, the coasts are omitted, because of the uncertainty with which their longitudes are known, and because otherwise this Mercator's Chart may be applied to any,

any, even the largest, seas between the North and South Polar Systems.

34. Thus may the grand problem of the longitude at sea be solved within the oceans limited by the Charts; a vast extent, through which the navigation of greatest consequence to the British Nation is performed, and in which by the usual method of sailing, through the uncertainty which attends it, and the deception arising from the currents, it is not to be wondered at, if ships are frequently deceived thereby some hundreds of miles. Nor is this all the use of the Variation Chart; but it is daily applicable for taking out the variation of the compass to be allowed in the course, the latitude and longitude by the reckoning being nearly known, the general use of which is known to all seamen, as being that for which all other variation charts have hitherto been drawn, without ever having been applicable for the longitude, within the limits before-mentioned.

35. It may be expected by some persons, that I should give a variety of examples, to make things plainer to the Reader. I have not given such calculations or examples, because the manner of making them is known to every Navigator, I mean the calculations proper to be made before the Variation Chart is to be applied, and the application of it needs no examples; nor do we often find in exemplifying Writers, such improvements as have been delivered by others. It is remarkable, that the greatest improver of navigation that ever was, Edward Wright, gives the fewest exemplary calculations of any, throughout all the parts of his Treatise.

36. It may be expected likewise, that I should have delineated the sea coasts of the Continents in this part of the work, that the situation of the ship to those coasts might appear by inspection; but, the delineation of coasts, whose longitudes are very imperfectly known, can be but of little use, and therefore are best omitted. The Variation Chart being designed for determining the longitude in those open seas within a degree, when that is found, it cannot be very difficult to sail a few hundred miles by the log line and compass, with some tolerable certainty, and from both of these methods to determine the place of the ship, for many parts of the ocean, and near the lands, where the lines of variation run too much

Eastings and Westings, to admit of the longitude by the variation and latitude only.

37. The Oceans most frequented, where the position of the variation lines are at present least favourable for this application, are, from the British Channel to the Northern Coast of North America; and that part of the Indian Ocean between New Holland and China, amongst the East India Islands; but in these latter parts the Islands are so near to each other, that there will always be frequent opportunities for correcting the ship's reckoning by a sight of the lands; on which account, if the method of sailing by log-line and compass in those parts, could not be depended on, the difference of longitude, between one place and another, might be taken within a degree, by the use of a good watch; and the application of such a machine I have shewn in my Treatise of Practical Astronomy.

38. As the variation lines on the Chart are chiefly drawn from a regular theory, and that is confirmed by the other observations, there cannot but be the fewer objections concerning them. The Islands St. Helena, Ascension, Trinidad, Tristan de Cunha, &c. become wholly regulated in longitude by the latitude and variation only; but there are other Islands in those Oceans, which have not had their longitudes settled by good astronomical observations, nor hath the variation of the magnetic needle been observed near them; if either of these and their latitudes were known, they might have been accurately placed in the Chart; but as they are not, these are omitted, with a design to make a table of them, and such notes as are proper. By the same method it is easy to settle the longitude of any new Islands that may hereafter happen to be discovered in those Oceans, although they are far remote from the lands; nor doth it seem altogether necessary to remind the ingenious Navigator of observing the variation, not only at all such Islands as are far distant from the Continent, but at all Capes and Headlands belonging to the Continent, as he is sensible of the use it may be of, in correcting the variation charts, from one period of time to another, if such delineations had no other use, but to supply the use of an observation which is now commonly made, to have the course more certain.

39. Here

39. Here follows an Example or two at large. Suppose a person at sea *May* 1st, 1780, in latitude $25^{\circ} 15'$ North; and before Noon he takes the altitude of the Sun's centre, which cleared from semi-diameter dip and refraction is $15^{\circ} 17'$, and at the same time, the bearing of the Sun's centre is taken by the azimuth compass $87^{\circ} 20'$ North Eastwardly, Required the longitude?

Co-latitude	$64^{\circ} 45'$	0.0436130
Co-altitude	$74^{\circ} 43'$	0.0156374
Polar Distance	$74^{\circ} 41'$	
Sum	214 9	
Half Sum	107 4	9.9804415
Remainder	32 23	9.7288253
Sum of the Logarithms		19.7685172
$40^{\circ} 0'$ Half Sum		9.8842586

$80^{\circ} 0'$ true Azimuth from the North.

$87^{\circ} 20'$ observed Azimuth from the North.

$7^{\circ} 20'$ Variation of the Compass Westwardly.

Answer 38. 28° Longitude West of London.

40. Suppose a person at sea *May* 1st, 1780, in latitude $6^{\circ} 15'$ North, and before Noon he takes the altitude of the Sun's centre, as before $15^{\circ} 17'$, when the Sun bears North Eastwardly $82^{\circ} 25'$ per compass. Required the longitude?

Co-latitude	$83^{\circ} 45'$	0.0025890
Co-altitude	$74^{\circ} 43'$	0.0156374
Polar Distance	$74^{\circ} 41'$	
Sum	233 9	
Half Sum	116 34	9.9515389
Remainder	41 53	9.8245267
Sum of the Logarithms		19.7942920
$37^{\circ} 54'$ Half Sum		9.8971460

$75^{\circ} 48'$ true Azimuth from the North.

$82^{\circ} 25'$ observed Azimuth from the North.

$6^{\circ} 37'$ Variation of the Compass Westwardly.

Answer 28. 18° Longitude West of London.

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41. A Table shewing the Angles which every Point, Quarter-Point, half Point and three Quarters of a Point of the Compass, makes with the Meridian.

				Points.	Quarters.	Degrees.	Minutes.
North.	South.	North.	South.	0	0	0	0
				1	1	2	49
				2	2	5	37
				3	3	8	26
N. by E.	S. by E.	N. by W.	S. by W.	4	4	11	15
				5	5	14	4
				6	6	16	52
				7	7	19	41
N. N. E.	S. S. E.	N. N. W.	S. S. W.	8	8	22	30
				9	9	25	19
				10	10	28	7
				11	11	30	56
N. E. by N.	S. E. by S.	N. W. by N.	S. W. by S.	12	12	33	45
				13	13	36	34
				14	14	39	22
				15	15	42	11
N. E.	S. E.	N. W.	S. W.	16	16	45	—
				17	17	47	49
				18	18	50	37
				19	19	53	26
N. E. by E.	S. E. by E.	N. W. by W.	S. W. by W.	20	20	56	15
				21	21	59	4
				22	22	61	52
				23	23	64	41
E. N. E.	E. S. E.	W. N. W.	W. S. W.	24	24	67	30
				25	25	70	19
				26	26	73	7
				27	27	75	56
E. by N.	E. by S.	W. by N.	W. by S.	28	28	78	45
				29	29	81	34
				30	30	84	22
				31	31	87	11
East.	East.	West.	West.	32	32	90	—

By

By the foregoing table, the course may be changed from degrees to points, or from points to degrees; and when half quarter points of the compass are to be introduced, one of these is to be reckoned $1^{\circ} 24'$.

42. A Table of Refraction from the Horizon to the Altitude of 42 Degrees, where it is but a Minute of a Degree, and therefore all above may be rejected in these operations.

Altit.	Refrac.	Altit.	Refrac.	Altit.	Refrac.
Deg. Mi.		Deg. Mi.		Deg. Mi.	
0 0	34	2 15	16	7 0	7
0 15	30	2 30	15	8 0	6
0 30	28	2 45	14	9 0	5
0 45	25	3 0	13	10 0	5
1 0	23	3 30	12	12 0	4
1 15	21	4 0	11	16 0	3
1 30	20	4 30	10	24 0	2
1 45	18	5 0	9	42 0	1
2 0	17	6 0	8		

When the altitude of either the Sun or a Star is taken, the refraction must be subtracted therefrom, because it makes the object appear more elevated than it really is. But before such subtraction, it is usual to add the semi-diameter, if it be the Sun's altitude that is observed, and his lower limb is brought to touch the horizon, although it would be truest to add it after the subtraction, and that semi-diameter may always be supposed 16 minutes in these observations.

43. A Table shewing how much the apparent Horizon is depressed by the Elevation of the Eye above the Surface of the Sea.

Elevation.	Depression.
Feet.	Minutes.
1	1
4	2
7	3
12	4
20	5
28	6
38	7
50	8

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44. A Table of the Declination of the Sun for a Bissextile Year, from my Practical Astronomy, p. 192.

Day.	January.	February.	March.	April.
1	23° 2'S.	17° 8'S.	7° 15'S.	4° 52'N.
5	22 39 S.	15 57 S.	5 43 S.	6 23 N.
9	22 8 S.	14 42 S.	4 9 S.	7 53 N.
13	21 31 S.	13 24 S.	2 35 S.	9 21 N.
17	20 46 S.	12 1 S.	1 0 S.	10 46 N.
21	19 56 S.	10 36 S.	0 34 N.	12 8 N.
25	19 0 S.	9 8 S.	2 9 N.	13 27 N.
29	17 58 S.	7 38 S.	3 42 N.	14 43 N.
Day.	May.	June.	July.	August.
1	15° 19'N.	22° 10'N.	23° 5'N.	17° 52'N.
5	16 29 N.	29 39 N.	22 42 N.	16 48 N.
9	17 34 N.	23 1 N.	22 18 N.	15 40 N.
13	18 35 N.	23 16 N.	21 45 N.	14 28 N.
17	19 31 N.	23 25 N.	21 6 N.	13 12 N.
21	20 21 N.	23 28 N.	20 22 N.	11 53 N.
25	21 6 N.	23 24 N.	19 32 N.	10 31 N.
29	21 45 N.	23 13 N.	18 36 N.	9 6 N.
Day.	September.	October.	November.	December.
1	8° 1'N.	3° 30'S.	14° 43'S.	21° 58'S.
5	6 33 N.	5 3 S.	16 57 S.	22 30 S.
9	5 2 N.	6 35 S.	17 7 S.	22 56 S.
13	3 31 N.	8 5 S.	18 33 S.	23 14 S.
17	1 58 N.	9 34 S.	19 13 S.	23 25 S.
21	0 24 N.	11 0 S.	20 8 S.	23 28 S.
25	1 9 S.	12 24 S.	20 57 S.	23 24 S.
29	2 43 S.	13 45 S.	21 39 S.	23 12 S.

Note. The years 1776, 1780, 1784, &c. are Bissextiles; and in these Bissextile years, the Sun's declination will be nearly the same again on the like days of the month; but for any intermediate days the following method is to be observed; suppose for instance, the Sun's declination be required for August 20, 1776, or 1780, the operation will stand thus;

August

August 17th,	Declination	13° 12' N.
21st,		11 53 N.
		25 5 — Sum.
19th,		12 32 30 Half Sum.
Sum of 19th and 21st,		24 26
20th,		12° 13' Answer.

If the declination is required for any day of a Bissextile year, it may be thus found by this short table, for the meridian of London at Noon; but if it be one year after the Bissextile, the answer is for the meridian of London on that day at 6 Afternoon; if two years after, it is for Midnight; if three years after, for 6 in the Morning the following day, on account of the return of the Bissextile year. And for any other meridian, allowance must be made according to the daily change of variation.

45. A Table shewing the Allowance to be made for the Variation of the Sun's Declination, to every 15 Degree of Longitude from London, the Daily Variation being given as in the first Column, in Minutes of a Degree.

Daily Var.	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
2	0	0	0	0	0	0	1	1	1	1	1	1
4	0	0	0	1	1	1	2	2	2	2	2	2
6	0	0	1	1	1	1	2	2	2	2	3	3
8	0	1	1	1	2	2	3	3	3	4	4	4
10	0	1	1	2	2	2	3	3	4	4	5	5
12	0	1	1	2	2	3	3	4	4	5	5	6
14	1	1	2	2	3	3	4	5	5	6	6	7
16	1	1	2	3	3	4	5	5	6	7	7	8
18	1	1	2	3	4	4	5	6	7	7	8	9
20	1	2	2	3	4	5	6	6	7	8	9	10
22	1	2	3	4	5	5	6	7	8	9	10	11
24	1	2	3	4	5	6	7	8	9	10	11	12

The application of this Table to more than 180. is evident.

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46. A Table of the Declination of some of the brightest Fixed Stars, for the Beginning of the Year 1780, taken from a Table of 300 Stars in my Practical Astronomy.

Stars of the Northern Hemisphere.

	Declination
The Pole Star, near the North Pole,	88° 8' N
Aldebaran, the Eye of the Bull,	16 3 N
Capella, in the Goat,	45 45 N
Procyon, in Canis Minor,	5 47 N
Regulus, or, Cor Leonis, the Lion's heart,	13 2 N
Arcturus, in Bootes,	20 21 N
Lyra, the brightest in the Harp,	38 35 N

Stars of the Southern Hemisphere.

Sirius, the brightest in the Heavens,	16 25 S
The Brightest in the Ship,	68 49 S
Spica Virginis, the Virgin's Spike,	10 0 S
The Brightest in the Centaur,	59 59 S
Antares, the Scorpion's Heart,	25 56 S
Fomahaut in Pisces, the Fishes,	30 47 S

The times when these Stars come to the Meridian, may be easily seen by a Delineation for that purpose, in my Practical Astronomy.

Although the Stars alter in declination every year, this table will serve for a considerable number of years in their application to this subject, without much error. If the bearing of the Star be taken by the compass, and the altitude taken at the same time, the process is like that for the Sun.

THE END